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COMMENTS ON THE QUESTION OF THE EXISTENCE OF A LUNAR MAGNETIC FIELD*

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Soon after their recent moon-impact, the Soviets announced[1] that the magnetometer on the vehicle had detected no evidence of a lunar magnetic field; the Soviet's instrument was capable of detecting fields down to 6×10^{-4} gauss. The impact occurred on the sunlit side of the Moon. The final magnetometer reading before impact presumably was obtained at a lunar altitude of the order of a kilometer, or more.

It is the purpose of this note to point out that this single piece of data is not sufficient evidence from which to conclude that the general lunar magnetic field is weaker than 6×10^{-4} gauss on the surface. It is suggested that, if a general lunar magnetic field existed, it would be confined by the solar corpuscular radiation, or solar wind, to a thin layer above the sunlit surface, but it could extend a considerable distance beyond the surface on the side away from the Sun.

An upper limit to the strength of magnetic field which can be pushed around by the solar wind can be obtained by a calculation of the momentum of the solar corpuscular radiation. If it is assumed that the proton density, n, is 500 cm^{-3} and that the average particle velocity, v, is 1000 km/sec, the

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momentum flux per unit area, or pressure, in the solar wind is $nMv^2 = 8 \times 10^{-6}$ dynes/cm^2. A pressure of this magnitude is capable of compressing a magnetic field until the magnetic pressure, $B^2/8\pi$, builds up to this size; the magnetic-field strength corresponding to this pressure $= \sqrt{8\pi \times 8 \times 10^{-6}} = 1.4 \times 10^{-2}$ gauss.

Recent observations by N. A. Kozyrev and by J. Dubois (see a recent publication by Z. Kopal[2]) of both the energy content and the time variations of the luminescence of some parts of the lunar surface indicate that this luminescence is, in large part, caused by solar corpuscular radiation incident on the lunar surface rather than by solar electromagnetic radiation. As the luminescence is observed only in sunlit regions of the lunar surface, it can be argued that the solar corpuscular radiation must have travelled essentially straight into the Moon's surface without being appreciably deflected by either a lunar or an interplanetary magnetic field. According to the argument in the preceding paragraph, the solar corpuscular radiation could not have reached the lunar surface if the Moon's surface magnetic-field strength were greater than $\sim 10^{-2}$ gauss.

These observations and their interpretation are consistent with the estimates of the strength of a possible lunar magnetic field based on various theories of the formation and history of the Moon; these estimates[3] range from zero to several hundred gamma (1 gamma $= 10^{-5}$ gauss).

Let it be supposed that, in the absence of the solar wind, the lunar magnetic field (B_0) would be a few hundred gamma or less on the surface. The protons and electrons in the solar corpuscular radiation are deflected by this field so as to set a current; the field resulting from this current tends to cancel the

Moon's field above the lunar surface and to add to it below the surface. The equilibrium properties of such a magnetic boundary layer can be calculated for the case of a cold plasma normally incident on a one-dimensional "moon" from the equations for such a plasma given by Davis, Lüst, and Schlüter[4]. If all the dependent variables but the magnetic field strength are eliminated from these equations, there results the differential equation

$$\frac{d}{dx}\left[\left(1-\beta^2\right)\frac{d\beta}{dx}\right] = \frac{4\pi e^2 n}{m}\,\beta$$

where

$$\beta^2 = \frac{1}{nMv^2}\,\frac{B^2}{8\pi}$$

Also, M and m are the proton and electron masses, respectively, and x is the distance from the lunar surface (measured negatively out from the surface in order that the plasma flow is in the positive x direction). This equation can be solved subject to the boundary conditions that the magnetic-field strength is $2B_0$ at the surface of the "moon" and zero at $-\infty$ with the result that

$$\sqrt{\frac{4\pi e^2 n}{m}}\,x = -\left[\sqrt{1-\frac{(\beta^*)^2}{2}} - \sqrt{1-\frac{\beta^2}{2}} + \ln\frac{\beta^*}{\beta} + \ln\frac{1+\sqrt{1-\frac{\beta^2}{2}}}{1+\sqrt{1-\frac{(\beta^*)^2}{2}}}\right]$$

where

$$(\beta^*)^2 = \frac{1}{nMv^2}\,\frac{(2B_0)^2}{8\pi}$$

For small values of β, ($B_0 << 7 \times 10^{-3}$ gauss), this expression can be approximated by

$$B = 2B_0 e^{-\sqrt{\frac{4\pi e^2 n}{m}}\,x} = 2B_0 e^{-4.2\,x(\mathrm{km})}$$

Thus, if the Moon had a surface field strength of less than ~ 700 gamma in the absence of the solar wind, the field would, according to this model, drop to 1/e of this value at ~ 500 meters above the surface on the sunlit side; this height is much less than the altitude of many of the lunar mountains. For an undistorted surface field as large as 700 gamma, the transverse displacement of the protons is only 8 meters.

This model is not completely realistic in many ways: For a three-dimensional moon, the current layer is curved, thus, the field strength at the surface is not exactly $2B_0$. Furthermore, the solar corpuscular radiation is not a cold plasma and, thus, a random velocity distribution will be superimposed on the flow previously described. Collisions between particles in the plasma were neglected; however, the mean free path for large angle collisions is orders of magnitude greater than the calculated boundary-layer thickness. All reflection of charged particles from the lunar surface has been neglected, as has any contribution from the solar magnetic field which may be trapped in the solar corpuscular radiation. Furthermore, a steady-state solution was found and all plasma oscillations were ignored. It is believed that corrections for these effects would either be small or would lead to a smaller boundary-layer thickness than that calculated.

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